Image Enhancement Based on Adaptive Median Filter and Wallis Filter

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Keywords: Noise Suppressing; Detail Enhancing; Image Enhancement

Abstract. Image enhancement has been an important technique for image analysis. The purpose of enhancement is suppressing noises and enhancing image details. However, most of algorithms only focus on the noise suppressing or detail enhancing. In this paper, an algorithm which could both suppressing noises and enhancing details through combining the adaptive median filter and Wallis filter is proposed. The adaptive median filter and Wallis filter are combined through the alternative strategy. Also, the strategy similar to the multi-scale enhancement is also performed to further enhancing the images. Experiments on various images verified that, the proposed algorithm performs effectively for both the noise suppressing and detail enhancing.

Introduction

Image enhancement is an important technique for image analysis [1]. Two of the main purposes of image enhancement is suppressing noises or enhancing image details. And, most of the algorithms are mainly for noise suppression [2-5] or detail enhancement [5-8].

Mean filter has been used for noise suppression and thus enhancing images. However, mean filter would heavily smooth image details. The nonlinear filters, such as median-type of filters [2], morphological filters [3, 4], partial differentiate equation based filters [5] and so on, have performed effectively for noise suppression. Although these nonlinear filters may preserve image details comparing with the mean filter, many of the image details may be still smoothed.

Also, may algorithms have been used for image enhancement. Histogram based algorithms [6] have been the widely used algorithm for image enhancement. But, the image details may be not well enhanced. Besides, many tools have been used for image enhancement, such as the possibility theory, differentiate equation, artificial intelligent tools and so on [5, 7, 8]. However, most of these algorithms are not effective for detail enhancement.

More importantly, the noises may affect the performance for detail enhancement. And, the detail enhancement may restrict the performance of noise suppression. Thus, it would be meaningful for proposing an algorithm which could suppress noises and enhance details both.

In this paper, an algorithm which could both suppressing noises and enhancing details through combining the adaptive median filter and Wallis filter is proposed. The adaptive median filter and Wallis filter are combined through the alternative strategy. Also, the strategy similar to the multi-scale enhancement is also performed to further enhancing the images. Experiments on various images verified that, the proposed algorithm performs effectively for both the noise suppressing and detail enhancing.

The Proposed Algorithm

Adaptive Median Filter

The adaptive median filter [2] has been an effective filter for impulsive noise removal, which could suppress impulsive noises more than 70%. Let $AMF_w(f)$ represent the image f filtered by adaptive median filter. Details about the $AMF_w(f)$ is in [2]. In adaptive median filter, w is the size of the window around one center pixel used for calculating the filtered result of the center pixel.

Wallis Filter

Wallis filter has been an effective filter for detail enhancement through contrast adjustment. The

expression of the filtered result of an image *f* could be expressed as follows [7].

$$WF_v(x, y) = \alpha \cdot [\, f(x, y) - m_f \,] + \beta, \quad (1)$$

where (x, y) is the pixel coordinate. α and β are the parameters. m_f is the local mean value of the current window with size *v*. When calculating *WF*, the original image *f* is firstly divided into non-overlap windows with the same size *v*. Then, the m_f of each window is calculated and then the *WF* could be calculated. Wallis filter could enhance image details through adjust the contrast of each small window. Then, the image could be enhanced adaptively following different application purpose.

Alternative Adaptive Median Filter and Wallis Filter

Noises usually existed in images, which would make the images unclear. So, an effective algorithm should well suppress the noises and enhance image details. Adaptive median filter which is a good tool to suppress the noises and may preserve the image details. Moreover, the Wallis filter performs effectively for image contrast adjustment which could enhance image details. Thus, it would be a direct way to combine the adaptive median filter and Wallis filter for both suppressing the noises and enhancing image details.

In this paper, we proposing an alternative way to combine the adaptive median filter and Wallis filter through alternatively operating the adaptive median filter and Wallis filter as follows.

$$AWF_{w,v}(f) = WF_v(AMF_w(f)). \quad (2)$$

In $AWF_{w,v}(f)$, the adaptive median filter is performed firstly to suppress the noises. Then, the Wallis filter is performed to enhance image details. This would suppressing the noises and enhance image details.

Multi-scale Extensions

Usually, the image noises may existed at multi-scale of images. Similarly, the image details have different sizes, which would also exist at multi-scale of images. Thus, the performance for image enhancement would be further extended through multi-scale extension of $AWF_{w,v}(f)$.

$AMF_w(f)$ smoothes noises corresponding to the size of window *w*. Then, changing the size of the window *w* would produce the multi-scale *AMF* for more effective impulsive noise removel [4]. Let w_i be the size of the window corresponding to the scale *i*. The multi-scale extension of $AMF_w(f)$ could be represented by $AMF_{w_i}(f)$.

Similarly, $WF_v(f)$ enhances image details corresponding to the size of window *v*. Also, changing the size of the window *v* would produce the multi-scale *WF* for more effective image detail enhancement. Similar to *AMF*, let v_i be the size of the window corresponding to the scale *i*. The multi-scale extension of $WF_v(f)$ could be represented by $WF_{v_i}(f)$.

Based on the multi-scale extension of adaptive median filter and Wallis filter, there are three types of multi-scale extension for $AWF_{w,v}(f)$.

Type 1: Multi-scale extension of $AMF_w(f)$ and fixing $WF_v(f)$ which leads to the multi-scale extension of $AWF_{w,v}(f)$ as follows

$$AWF_{w_i,v}(f) = WF_v(AMF_{w_i}(f)). \quad (3)$$

This type of multi-scale extension mainly extends the performance of adaptive median filter for noise suppression.

Type 2: Multi-scale extension of $WF_w(f)$ and fixing $AMF_v(f)$ which leads to the multi-scale extension of $AWF_{w,v}(f)$ as follows

$$AWF_{w,v_i}(f) = WF_{v_i}(AMF_w(f)). \quad (4)$$

This type of multi-scale extension mainly extends the performance of Wallis filter for detail enhancement.

Type 3: Multi-scale extension of $AMF_w(f)$ and $WF_v(f)$ which leads to the multi-scale extension of $AWF_{w,v}(f)$ as follows

$$AWF_{w_i,\ v_i}(f) = WF_{v_i}(AMF_{w_i}(f)). \quad (5)$$

This type of multi-scale extension both extends the performance of adaptive median filter for noise suppression and the performance of Wallis filter for detail enhancement.

These three types of multi-scale extension could be selected for different application purposes.

Experimental Results

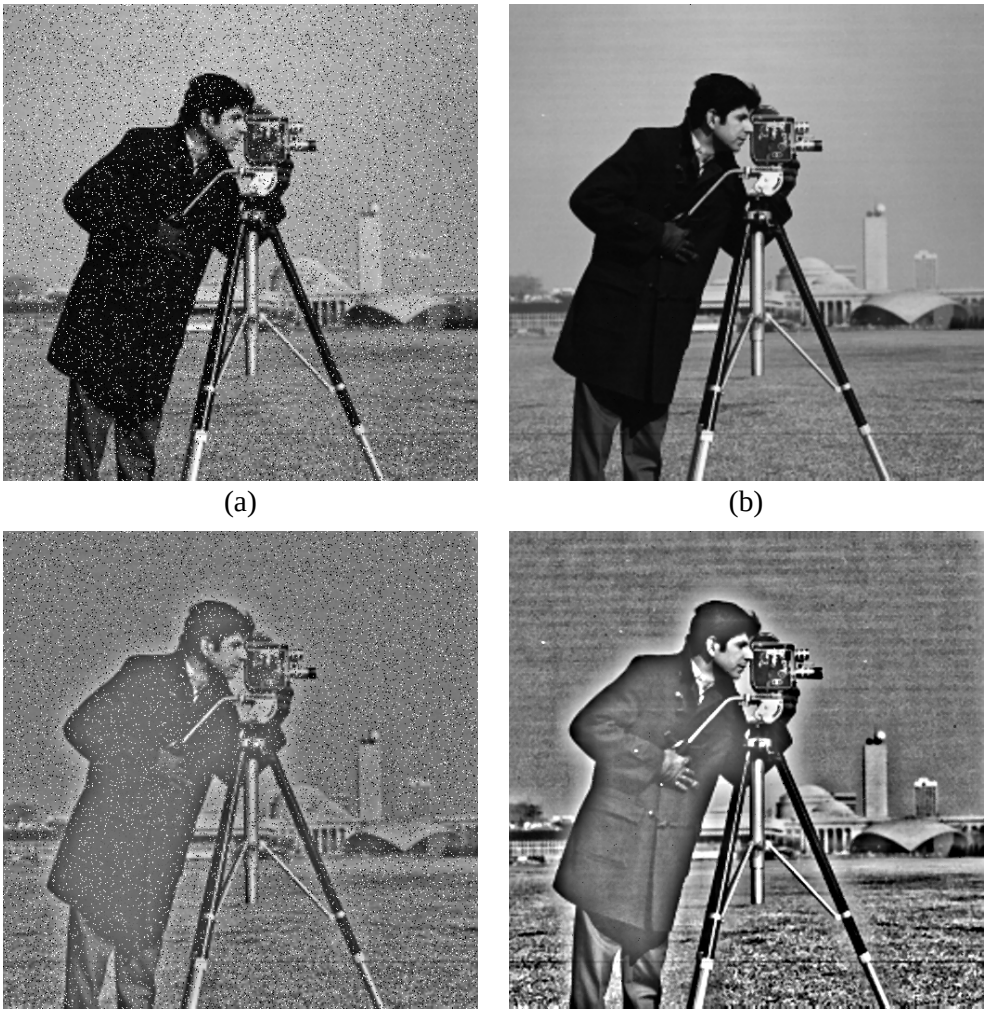
To verify the effectiveness of the proposed algorithm. Different types of images are used. Fig. 1 is an example of image enhancement using the Lena image. (a) is the original image. (b) is the result of *AMF*. (c) is the result of *WF*. (d) is the result of the proposed *AWF*.

(a) (b)

(c) (d)

Fig. 1. Enhancement example of Lena image

The original Lena image contains noises and the details in the dark regions are not clear. The result of *AMF* could well smooth the noises and enhance the visual effect of the image. However, the details in the dark regions are still not clear. The result of *WF* enhance some details, but the noises are still heavy. The result of the proposed *AWF* could effectively suppress the noises and the details of the whole image are clear and rich. This example indicates that the proposed *AWF* is effective for enhancing images which contains noises and has unclear details. Thus, the proposed *AWF* is effective for image enhancement.



(a) (b)

(c) (d)

Fig. 2. Enhancement example of Cameraman image

Fig. 2 is an example of enhancement using the Cameraman image. (a) is the original image. (b) is the result of *AMF*. (c) is the result of *WF*. (d) is the result of the proposed *AWF*. Also, the original Cameraman image contains noises and the details in the dark regions are not clear. *AMF* could only enhance image through smooth noises and *WF* could not suppress noises while enhancing image. Thus, the performances of *AMF* and *WF* are not good. The result of *AWF* could both smooth noises and enhance image details. Therefore, the proposed *AWF* performs effective for image enhancement.

Fig. 3 is another example of image enhancement. (a) is the original image. (b) is the result of *AMF*. (c) is the result of *WF*. (d) is the result of the proposed *AWF*. Again, the proposed *AWF* could both smooth noises and enhance image details, which performances effectively for image enhancement.

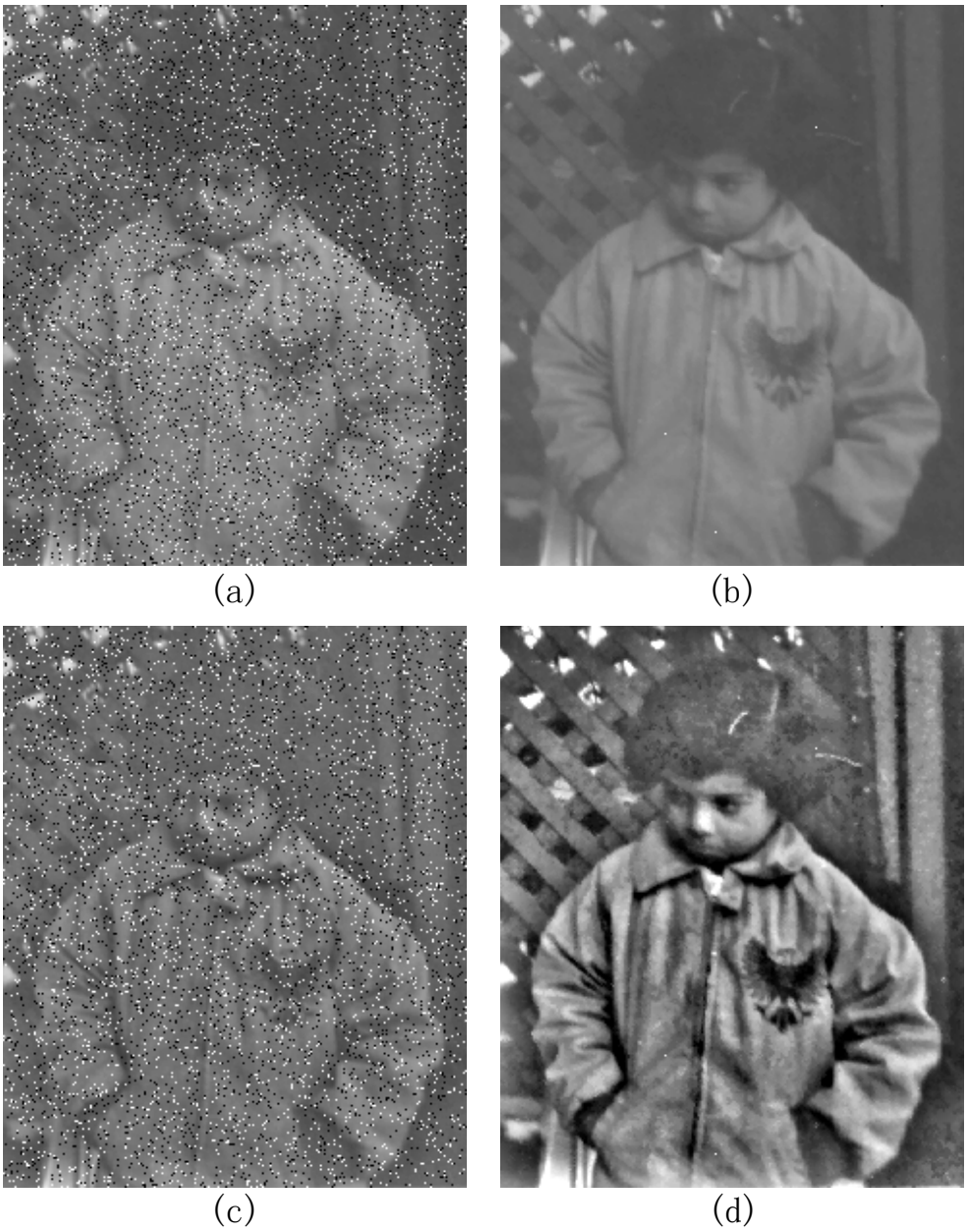


Fig. 3. Another enhancement example

All of these experiments verified that, the proposed algorithm could effectively enhance image details and suppress noises, especially the impulsive noises. In this way, the proposed algorithm could be well used for different types of applications related to noise suppression and detail enhancement.

Conclusion

Suppressing noises and enhancing image details are crucial for image enhancement. An algorithm which could both suppressing noises and enhancing details through combining the adaptive median filter and Wallis filter is proposed in this paper. The adaptive median filter and Wallis filter are combined through the alternative strategy. Also, the strategy similar to the multi-scale enhancement is also performed to further enhancing the images. Then, the performance of enhancement could be further extended. Experiments on various images verified that, the proposed algorithm performs effectively for both the noise suppressing and detail enhancing. Therefore, the proposed algorithm could be effectively used for image enhancement related applications, such as segmentation, image registration and so on.

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